Health and Fitness IoT Devices 2018

Abstract: A close look at connectivity for IoT devices related to health and fitness applications, ranging from fitness trackers to continuous glucose monitoring and similar wearable devices. A five-year forecast provides insight into market growth based on changing insurance payment and government/regulatory conditions.

MOBILE EXPERTS

October 2018

Health + Fitness IoT Devices 2018

FIGURES

CHARTS

MOBILE EXPERTS

IoT Special Report:

Health + Fitness IoT Devices 2018

MEXP-IOT-HEALTHCARE-18
November 2018

1 EXECUTIVE SUMMARY

Telemedicine has been a buzzword for twenty years, and frankly it's become a meaningless word by now. The fact is that the idea of improving health and fitness with technology has changed radically since 1995. Instead of thinking of a "Jetsons" scenario with a video chat, it's really much more about monitoring the body constantly, adding special devices when medical conditions justify it.

First of all, there's a major trend toward prevention instead of simply treating medical problems. It starts with fitness devices, tracking our workouts and our sleep patterns and other aspects of daily life. The health-care establishment has latched onto these devices and has created its own array of monitoring devices for blood pressure, temperature, glucose levels, and many other medical indicators.

New business models are developing. Insurance companies now provide incentives for fitness activity. Government regulations have changed to directly incentivize hospitals for monitoring patients….and penalize any healthcare provider that does not monitor patients well enough to prevent readmissions.

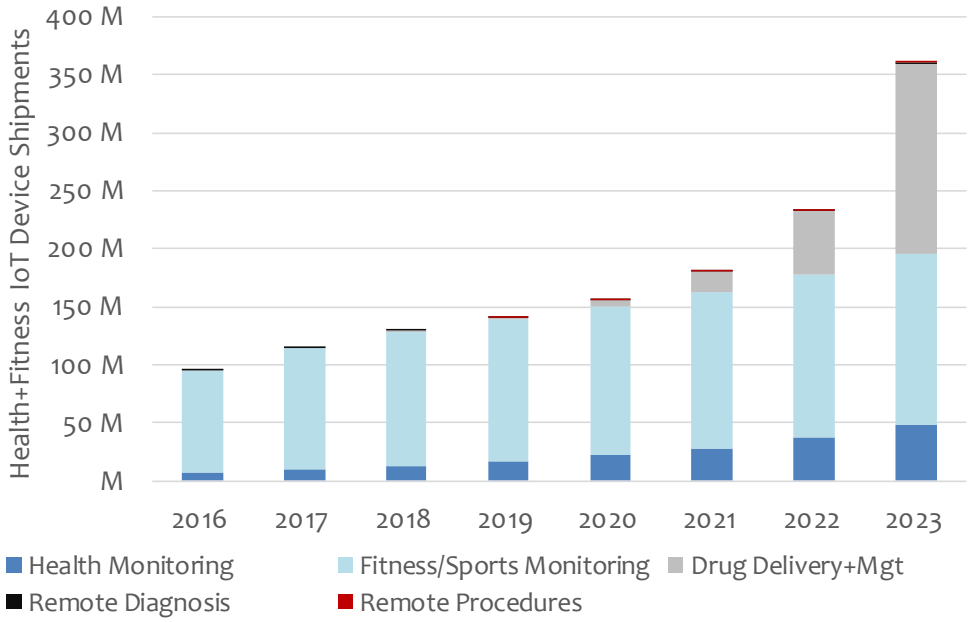

Chart 1: Health+Fitness IoT Devices, by application, 2016-2023

Source: Mobile Experts.

Medical implants have used licensed RF technology for many years, using special licenses in the 400 MHz range. The American MICS bands have been adopted almost worldwide, and the number of implants using MICS/MedRadio connectivity keeps growing every year. These devices will become more sophisticated but the RF format should be very stable.

Doctors will increasingly use video chat and other broadband connectivity to do their jobs. In this report we highlight the likely use of remote diagnostic sensors so that a doctor can observe a patient's vital signs during the ambulance ride. It's not just about video.

The logical extension of remote diagnostics will be the ability for doctors to perform various procedures remotely. "Remote Surgery" is a dramatic way to describe this, and the concept gets a lot of attention. Our forecast includes very small numbers of robots to perform a variety of medical procedures remotely. This may become more common after about 2022, but we don't see major growth of this application during our 5-year time horizon.

Overall, we have begun on a broad sweeping change in healthcare, where the business model will change completely. Instead of payments for transactions, doctors and hospitals will be paid to keep people healthy. It will not happen quickly… we expect at least 20-30 years for the market tectonics to shift. Technology and the IoT play a role to enable this shift, and we will see growth during the next five years to move hospitals, insurance companies, and patients toward the new business model.

2 KEY APPLICATIONS

The healthcare market is very broad in itself, so there are too many IoT applications to cover in one report. Looking at the big picture of healthcare and fitness altogether, communications applications fall into five categories:

- Consumer fitness and sports monitoring
- Patient medical device monitoring
- Medicine management
- Telemedicine
- Asset tracking for medical equipment

Each of these areas is rich with variety, with hundreds or thousands of variations. This report focuses on the most significant shipments from a commercial point of view. Focus areas include:

FITNESS AND SPORTS DEVICE MONITORING:

Wearable devices for fitness enthusiasts have grown rapidly over the past four years, with shipments of 116 million devices in 2017. Many of these devices are used to track fitness routines for serious athletes, but the market growth is coming from the "everyday" devices which also track sleep patterns and the steps involved with a normal daily routine.

As Chinese companies such as Xiaomi offer devices below $30, and other companies like Garmin offer specialized devices for specific sports, the market will continue to grow steadily. In these cases, the information collected is generally for the consumer, to simply track his or her activity.

As these devices become more common, the lines between fitness and medical monitoring are becoming blurred. Tracking sleep patterns can be interesting for the consumer, but could be considered medical data to a doctor. Insurance companies are starting to cross the lines between "medical" information and "fitness" information as well, offering rebates on premiums for customers that exercise.

We've grown more optimistic about smart-watches serving as fitness and health monitors, as Qualcomm has recently introduced a co-processor that can run some simple monitoring and timekeeping applications at very low power. Why is this important? Because the biggest hindrance to growth in the fitness/smartwatch market has been the poor battery life of the devices. We expect to see a significant improvement over the next year.

This report tracks the number of wearables in fitness, wellness, and outpatient medical applications all together, because the devices are very similar and, so far, the wireless technology used is identical.

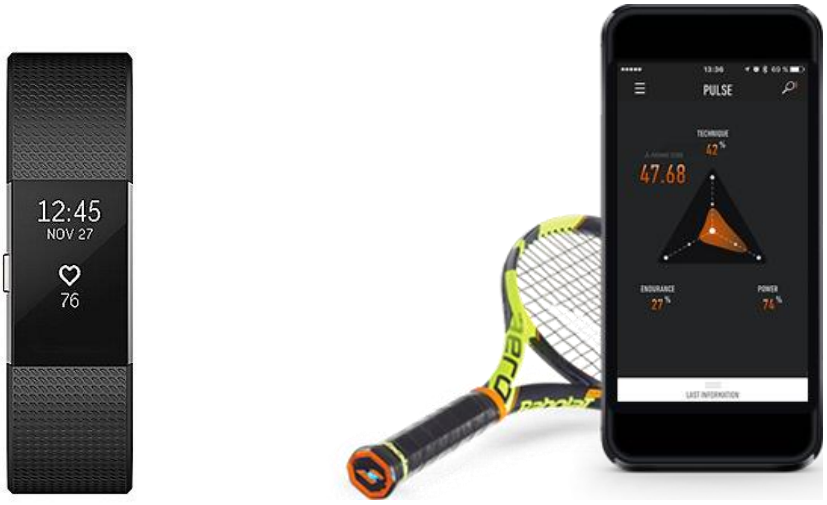

Figure 1 A fitness wearable device and a connected tennis racket

Sources: Fitbit, Babolat

CLINICAL MONITORING (GLUCOSE AND OTHER):

Devices to monitor patient health more closely often move beyond heart rate monitoring, to monitor more specific medical data such as glucose levels, blood oxygen levels, blood pressure, temperature, and other factors. Continuous Glucose Monitoring has been the most successful application so far, with roughly 800 million patients served today by companies such as Dexcom and Medtronic.

The CGM market is also quite lucrative, driving as much as $2B in revenue during 2017 (mostly related to service and sensors). Most devices use Bluetooth today, but readers use LTE backhaul.

Clinical accuracy for tests such as glucose or blood oximetry can be difficult with a patch, but sensing heartrate, movement, and blood pressure can be achieved with external devices. Many devices that do not break the skin don't need FDA certification, so this market is expected to grow steadily.

Figure 2 A "smart patch" for clinical monitoring

Source: Karten Design

Figure 3 The Dexcom Continuous Glucose Monitoring System

Source: Dexcom

DRUG DELIVERY AND MEDICINE MANAGEMENT:

Many devices have been proposed with micro-needles to titrate and deliver drugs based on a closed-loop system with sensors worn on the body. This concept has merit due to the long list of medical problems that ensue when patients make mistakes with medication.

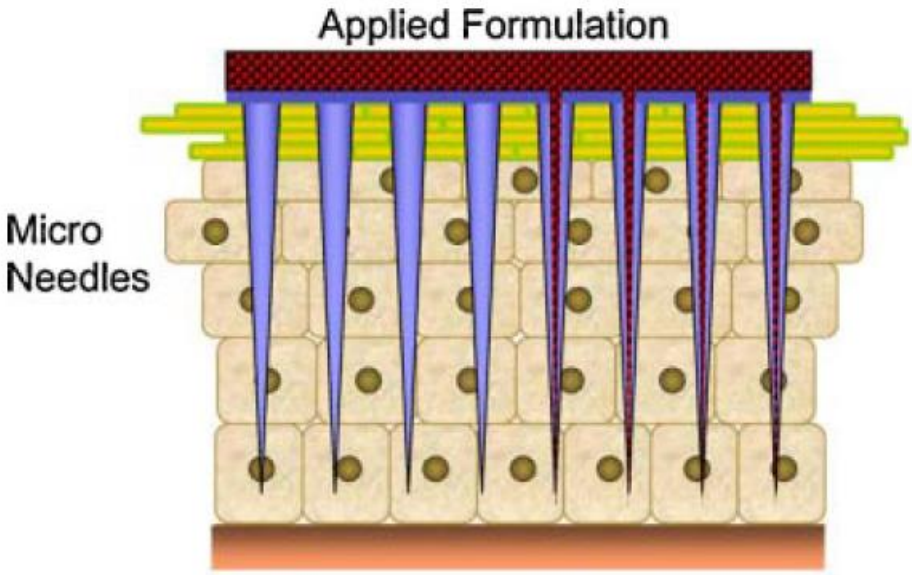

Figure 4 Microneedle approach to drug delivery

Source: Journal of Pharmaceutical Sciences

It's clear that devices for drug delivery will be slow to reach the market due to safety concerns, but after more than 10 years of development so far, some devices have reached a level of maturity.

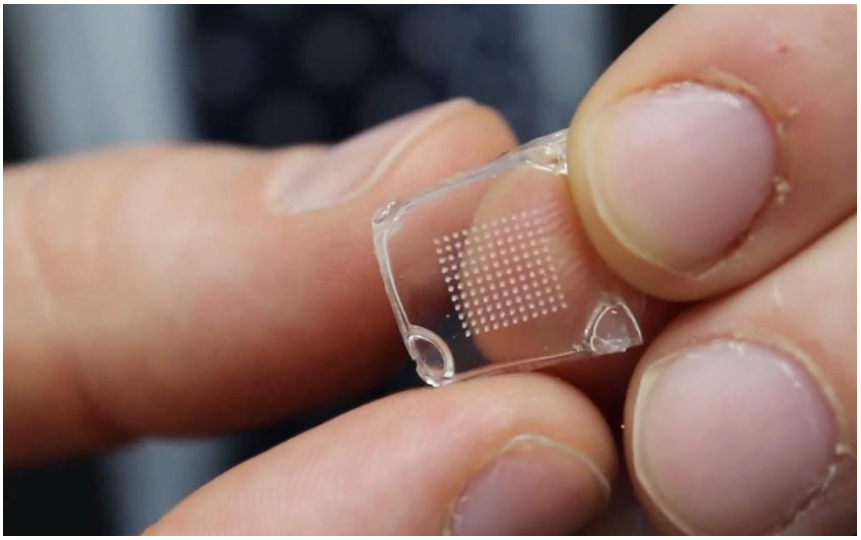

Figure 5 Microneedles fabricated with polymer materials

Source: Youtube/BBSRCMedia

Of course, the first step in the use of automated drug delivery systems will be the supervised use of technology like microneedles, to verify that the device delivers the appropriate amount of the drug as expected. We believe that integration of sensors with drug delivery systems could come rapidly for some applications (artificial pancreas) but will take longer for other applications. U.S. FDA clearance will determine the schedule of commercial deployment in almost all cases, because the USA represents one of the largest and most lucrative health-care markets.

Another, simpler application is the smart pill dispenser. Working in most cases together with an app on a smartphone, the smart pill bottle reminds the user to take his/her medication, and can alert users or doctors whenever the pill bottle is opened to counter tampering or overmedication.

Figure 6 Smart pill bottle using an LTE radio

Source: Adhere Tech

Smart pills could be another possible application, with capsules that report information during or after transit through the body. We believe that this technology could be limited in use for the next five years, with lengthy FDA and other regulatory processes to validate safety and efficacy. We have not focused on this opportunity in this year's study.

TELEMEDICINE OR TELEHEALTH:

The concept of remote diagnosis of a patient has clearly been around for a long time, since the telephone was invented. As telecom infrastructure matured in the 1990s and 2000s, video conferencing became possible and the concept of "telemedicine" has been around for a long time.

Smartphones make two-way video discussion with a remote doctor much more affordable and convenient. We consider this application to be a part of the mobile broadband market, not the IoT market, because it's inherently a human use of telecom technology.

The next step, however, will be for doctors to operate some kind of equipment remotely. Remote surgery may be performed by a specialist in a very obscure procedure, using generic equipment at a local hospital. This application will require very low latency for precise control, as well as high throughput for high-definition video or even augmented reality goggles. Mobile Experts has forecasted some small quantities of these systems in our 5G

IoT forecast (see the Outlook section), but due to the low volume and the late introduction of equipment (around 2021-2022) the remote medicine application is not a central focus for this report.

ASSET TRACKING IN HOSPITALS:

For the past 20 years, hospitals have invested in real-time location systems (RTLS) for their expensive machines. Hospitals have a unique requirement, with millions of dollars of assets on wheels that can get lost in the corridors of a large building. Systems ranging from Zigbee to BLE have been used in these cases so far.

Mobile Experts will be including devices for this application in a separate forecast for Asset Tracking in general. Although the end customer is the hospital, the technology choices, business model, and purpose for the equipment is really the same as the oil & gas industry, truck fleets, and shipping companies.

In short, the asset tracking application is not included in the Healthcare forecast because the overall purpose of Asset tracking is about asset utilization, and not about healthcare.

3 MARKET DRIVERS AND CHALLENGES

The healthcare market has seen some sweeping changes over the past six years, with regulatory and business model changes in the USA causing a major disruption in the world's largest healthcare market.

REGIONAL DIFFERENCES IN HEALTHCARE ECONOMICS:

In many ways, the American market drives the overall world market for innovation in healthcare devices, due to the generally open market in the USA. Compared with the top-down government healthcare model used in Europe, China, and Canada, the US system remains pretty open and flexible. The US market will constitute the single biggest market driving IoT device adoption because of the large dollar values involved in American healthcare.

Here are a few notes on individual markets for healthcare:

- Japan: Private insurance (paid by employers) covers most people. Retired, unemployed, and others get government subsidized insurance plans. Japan uses a Fee-For-Service approach overall.
- France: Socialized medicine, but 92% of people have complementary private insurance to get access to higher quality care. Private insurance companies pay about 13% of health care spending. Patients have significant co-pay
- Germany: Socialized medicine, with 9% of people also buying complementary private insurance. Fee-for-service system with very few costs to the patient.
- China: The government set up three health insurance systems in the 1990s: Urban Employees, Urban Residents, and Rural Cooperative Medical Insurance. Government picks up the bill for urban and rural residents for basic coverage, and urban workers get supplemental insurance where premiums are paid by employers.
- United States: Recent legal changes in the USA have dramatically increased the cost of health insurance, leaving large numbers of people uninsured or with high-deductible insurance plans. Roughly half of the US population has employer-funded insurance coverage, with 7% of people buying private coverage and 36% on government plans.

SHIFTING REVENUE FROM COMMERCIAL TO GOVERNMENT:

As Veterans Administration, Medicare and Medicaid programs grow in the United States, an increasing share of revenue is paid through government programs. This is the slow process of the United States gradually adopting socialized medicine, as in Canada, Europe, and China. Today, we estimate that more than half of US healthcare spending is covered by various government programs, and by 2020 we expect that 70% or more will run through government programs.

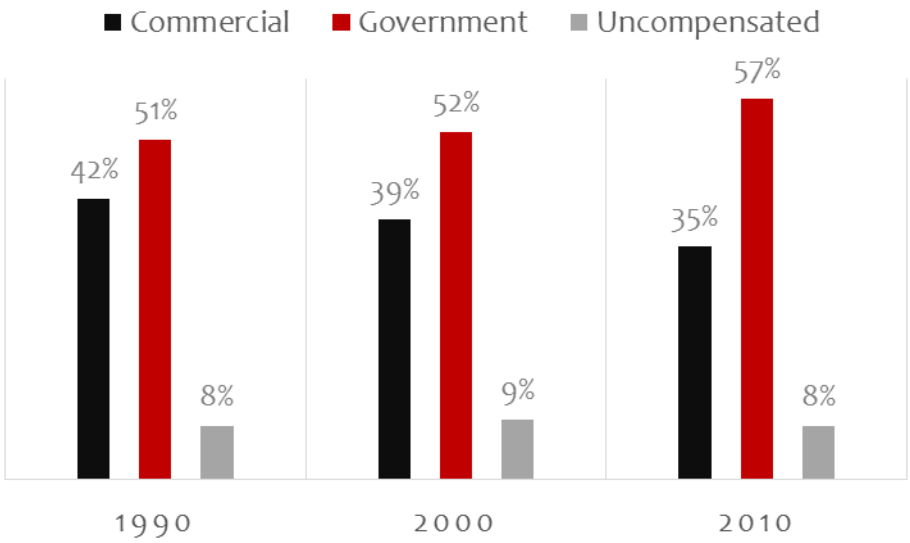

Figure 7 Shifting Revenue from commercial to government in USA

Source: American Hospital Association Annual Survey

VALUE-BASED PAYMENT VS. FEE-FOR-SERVICE:

Many people realize that the traditional American approach of asking insurance companies to pay for any procedure recommended by a doctor is wasteful. Doctors are incentivized to be careful, asking for all possible tests and prescribing medications in a transaction-based mentality---where neither doctor nor patient are paying the bill for the transaction.

Perversely, in this existing model doctors make more money if their procedures are unsuccessful, or if complications arise. Common sense calls for a better system.

The Value-Based Payment model is a strategy to promote "wellness" instead of transactions. The US healthcare industry is slowly moving toward this mindset, with about 10% of healthcare providers now billing based on the health of patients, instead of billing for healthcare transactions.

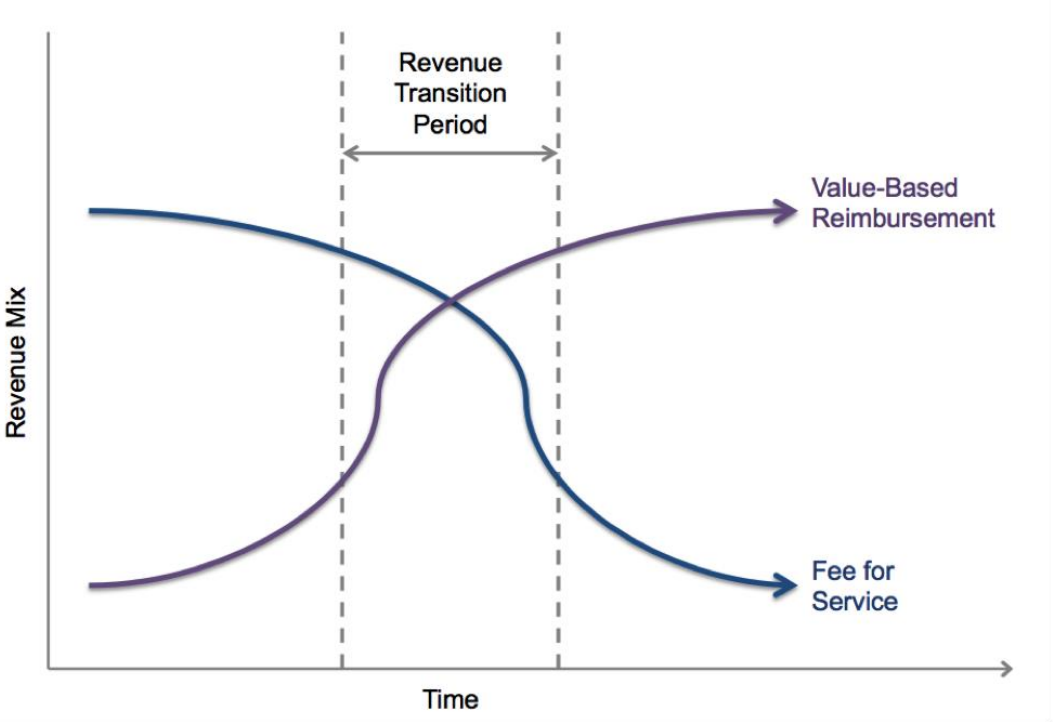

Figure 8 The Business Model Change to Value-Based Reimbursement

Source: HealthCatalyst

One important part of the transition to VBP is the ability to track 30-day readmissions. Typically, after surgery an infection arises in between 2% and 5% of patients. These patients must be readmitted and treated---and 3% of these people die.[1] The US Medicare program requires hospitals to track 30-day readmissions rates for heart attack, heart failure, and pneumonia, and many track surgical patients as well. Health systems must also track 90-day readmissions. Medicare penalizes hospitals that fail to meet stastical standards for performance in this area, incentivizing improved performance.

The mechanism for transition to a VBP model will take the following steps:

Category 1: Fee For Service: No Link to Value

Category 2: Fee For Service: Linked to Quality of care. This step can include penalties for readmissions and bonuses for physicians or healthcare facilities.

Category 3: Alternative Payment Models: This step involves shared savings plans and some shared risk terms.

[1] Centers for Disease Control, Surgical Site Infection statistics January 2016

Category 4: Population-Based Payment: This longterm business model is not well defined, but the concept implies that a hospital or healthcare organization would receive a government payment based on the population served in their area of coverage.

In parallel with these government-defined steps, other activity shows promise in the market:

- Insurance companies are starting to offer rebates to customers that exercise regularly, or achieve fitness targets (such as an 8-minute mile). This trend represents a willingness to shift cost toward the insurer for healthier patients, using technology as an enabling tool to identify eligible customers.
- Insurance companies offer incentives to doctors, for metrics ranging from full immunization of kids to readmission for diabetes or cardiac patients. In many cases monitoring devices can be used to refine the metrics, more closely aligning them with health factors such as glucose levels or heartrate.
- Employers that fund health insurance plans are also offering financial incentives to employees that exercise…representing cost savings shared between the insurance company, the employer, and the employee.

VBP will grow in the market by taking steps as outlined here. Bonuses and penalties are a start, with shared savings plans becoming a preferred business model in the next few years. Shared risk models (where savings and risks are shared by insurers and providers) will come next. In our view, the "full risk" step outlined here is unlikely due to the inability to control everything in healthcare—there will always be some element of shared risk.

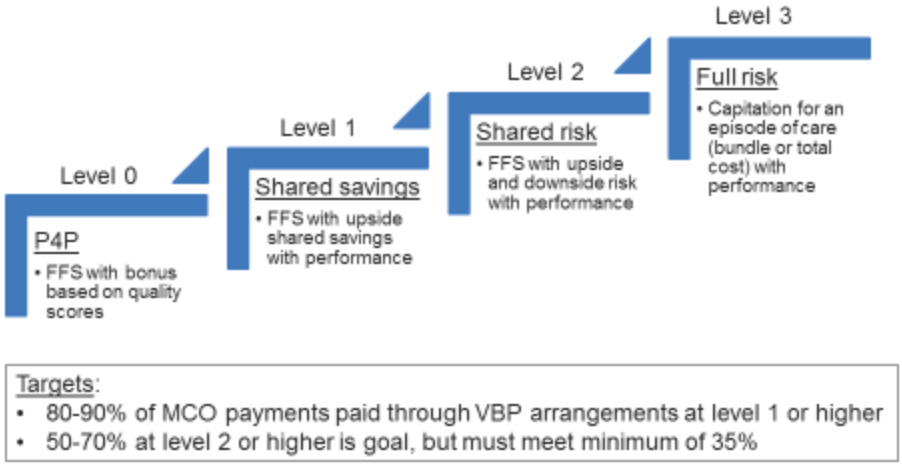

Figure 9 Shifting Revenue from commercial to government in USA

Source: CareCompass Network

Clearly, many of these "wellness" concepts rely heavily on patient monitoring in order to quantify the health of the patient in specific measurements. This is the most important driving force behind healthcare IoT growth.

The US Government has taken this challenge on itself (which seems appropriate since the US Government now pays for most healthcare in the USA). The Department of Health & Human Services announced that 30% of Medicare payments involved an alternative payment model tied to quality by December 2016. However, since 2016 the progress appears to have slowed down, as the government has not released new figures.

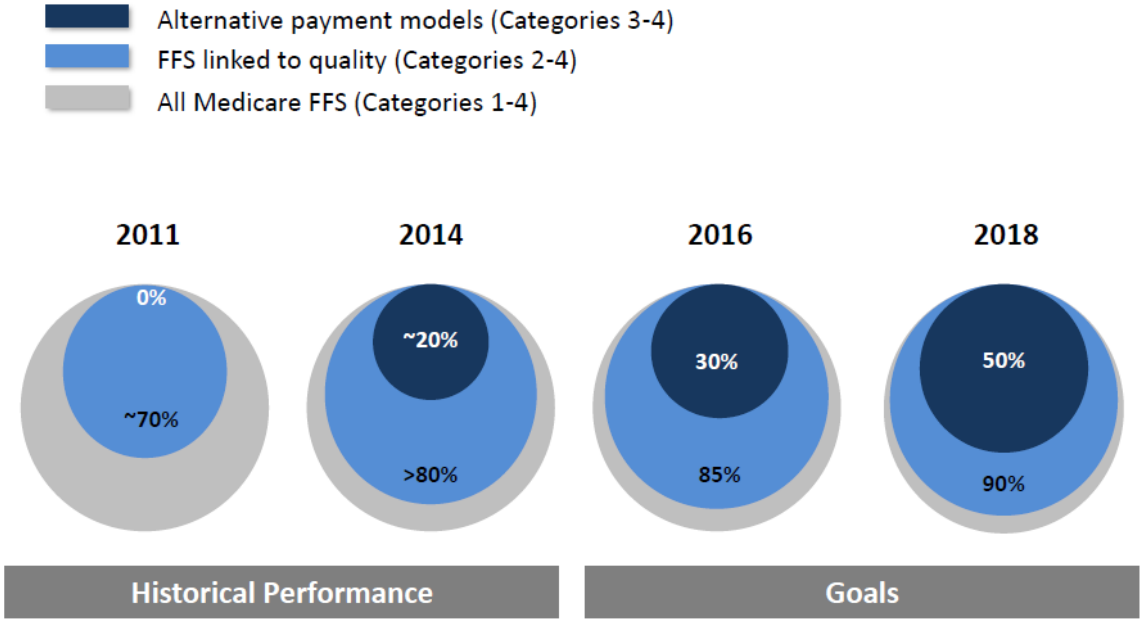

Figure 10 US Government goals for Value Based Payment models

Source: CareCompass Network 2016 goals

REGIONAL GOVERNMENT REGULATIONS:

The Affordable Care Act (commonly called Obamacare) has become a significant market driver toward patient monitoring. One of the objectives of the ACA was to push the American health-care market closer to a "wellness" model instead of the fee-for-service model. As one example, the ACA imposes a Medicare penalty on hospitals with readmissions above a level determined by a government board.

In Europe, wireless medical devices are covered by two regulatory frameworks: the Radio Equipment Directive (RED) and the EU Medical Devices Directive (MDD), soon to be replaced by the Medical Device Regulation (MDR). RED replaced the previous R&TTE radio

requirements in June 2016, and is intended to govern radio requirements so that the same product can be sold throughout Europe. MDD/MDR is intended to rationalize regulations among all different European countries with regard to all kinds of medical devices, and basically governs the efficacy and safety of medical products. Products meeting these regulations can carry the CE marking—a basic requirement to sale of a medical product in Europe.

In Asia, the Chinese CFDA, Japanese PMDA, and other agencies set the regulations for medical devices. Many device manufacturers consider Japan's PMDA to be the most difficult agency to clear, but there is some collaboration between the US FDA, PMDA and other countries which is intended to speed up device approvals for each regulatory agency.

Overall, the strongest regulatory incentives to use monitoring technology also are found in the US market, where payment models are starting to move toward Value-Based Payment and liability concerns are driving practitioners to track patients more closely.

INSURANCE COMPANIES:

Health insurance and life insurance providers have a financial incentive to insure patients with good health. Traditionally, policy pricing has been based on physical and medical examinations, and in some cases insurance companies have paid for gym memberships. Despite paying for gym membership, the insurance companies were not able to verify the number of visits to the gym or the activity level in the gym.

During the past two years, plans are emerging which supplement the doctor's exam with IoT device monitoring. This makes the insurance incentive much more likely to target the right customers.

Over the next five years, we expect that this trend will grow from the fitness tracking market to the healthcare tracking devices. Insurance companies will offer incentives to healthcare providers (doctors and hospitals) to use various tracking devices to avoid readmissions and catastrophic health conditions.

Some of the companies offering these incentives are not insurance providers. Vitality is one example of an organization—Part of Discovery Group, Vitality is a wellness program—that offers a plan to consumers and collects incentive money from insurers and/or employers. The end user earns "status" points and rewards, free gym membership, discounted insurance rates, and other goodies. Discovery/Vitality is now connected with Prudential, John Hancock, Generali, Ping An Health (China), and Discovery Life in their home market of South Africa.

Insurance Incentive Provider	Incentive
Cigna	Up to $500 rebate
Humana	10% premium discount
Oscar	$240 in gift cards per year
Premera	7.5% premium discount or $100 gift card
Tufts Health Plan	2.5% premium discount
United Healthcare	Up to $1500 premium discount per year

Figure 11 Examples of insurance incentives to use fitness tracking

Source: Mobile Experts

4 TECHNOLOGY OPTIONS

Looking at the broad variety of fitness and medical monitoring devices available today, it seems clear that most Healthcare IoT devices will fall into a few technology categories:

1. MICS and WMTS legacy devices;
2. Bluetooth and ANT/ANT+ devices;
3. Zigbee and other 802.15.4 devices;
4. 802.15.6 radio devices;
5. Wi-Fi devices;
6. GSM, 3G, and LTE devices
7. Narrowband IoT devices will enter the healthcare market during the next year.

MICS (MEDRADIO)

Wireless telemetry has been around for a long time in the hospital, and two examples of telemetry gear are already well established in the market.

Medical Implant Communication Service was originally set up at 402-405 MHz with low transmit power, specifically to communicate with implanted medical devices. The FCC in the USA added spectrum, extending to the 401-406 MHz band in 2009. In addition, in 2011 and 2012 additional spectrum was designated, including 413-419 MHz, 426-432 MHz, 438-444 MHz, 451-457 MHz, and 2360-2400 MHz for implanted devices. Generally this service does not communicate with any gateways on a routine basis, but only by a human user with a reader device. Based on the human user case, these devices are not counted in our IoT estimates. In the future, this may changes as the recently added spectrum ruling envisioned prosthetic limbs and other functions to restore movement and sensation for the user….and these sophisticated devices may start to connect to a network at some point.

Figure 12 Examples of a MICS implantable device and reader

Source: Biotronik

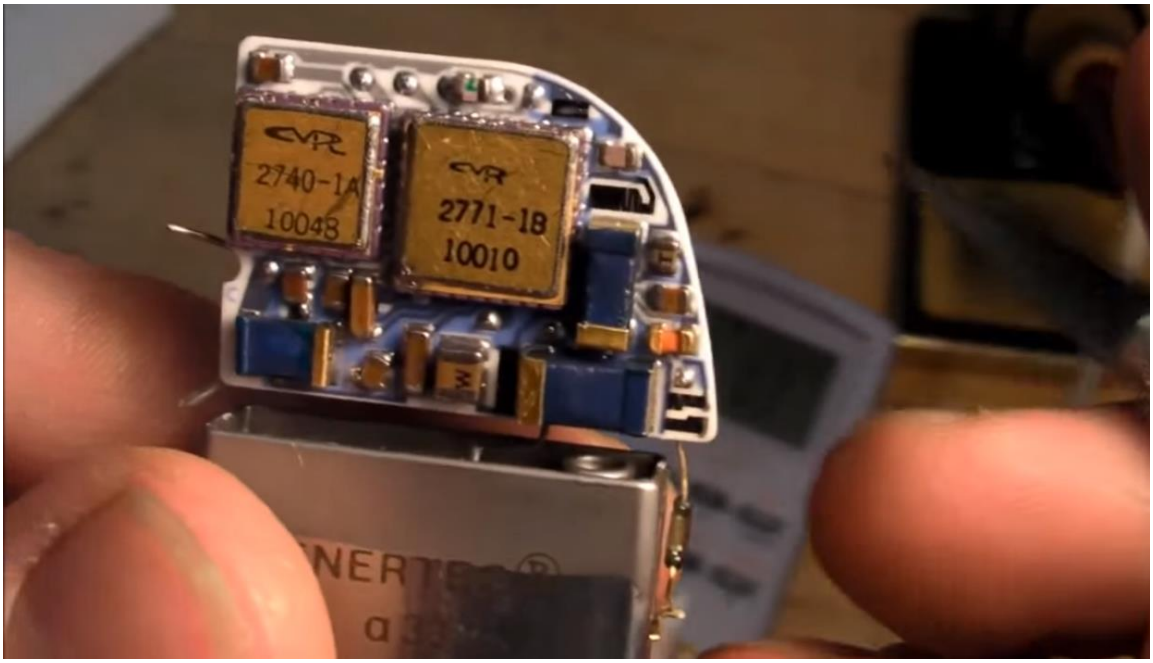

Figure 13 Teardown of an implantable defibrillator with MICS connectivity

Source: Youtube/Eric Wasatonic

WMTS

Wireless Medical Telemetry Service (WMTS) devices operate at 608-6014 MHz, 1395-1400 MHz, and 1427-1432 MHz. Outside of the USA, similar devices are used in ISM bands. These devices are only used within the hospital, for datalinks related to patient monitoring equipment such as heartrate monitors and other devices.

There's not much ongoing development, but hundreds of existing products utilize radios in these bands for sensors in the hospital. For cost and higher security, we expect these radios to migrate to new radio formats over time.

BLUETOOTH AND BLE (BLUETOOTH 4.0)

With the arrival of BLE and its very low power consumption, this format has taken the majority share of wearable devices. Roughly 97% of wearable devices used BLE in 2015, with variations (see ANT below) taking the rest.

BLE adapts the old Bluetooth standard by limiting the time to send data to 3 milliseconds, compared to 100 milliseconds for Blutooth "classic". In addition, BLE uses a slow acknowledgement approach to save on power. The net impact is that power consumption can be 50% to 90% reduced, compared to a Bluetooth 2.0 baseline.

BLE uses 128-bit AES encryption, so it is generally accepted as HIPAA-certifiable with the right implementation.

ANT AND ANT+

Using the physical layer of Bluetooth with GFSK modulation and AES-128 security encryption, Dynastream (a subsidiary of Garmin) developed ANT for specialty sports applications. ANT uses adaptive transmissions at regular time intervals to implement ultra-low power consumption, with large numbers of devices on a shared channel. Up to 65,000 devices are theoretically possible on a shared ANT channel. Throughput is lower than Bluetooth implementations to allow for larger numbers of devices.

	BLE	ANT/ANT+	Zigbee
Frequency	2.4 GHz	2.4 GHz (2457 MHz for ANT+)	2.4 GHz
Modulation	GFSK	GFSK	OQPSK
Channel Bandwidth	2 MHz	1 MHz	2 MHz
Configurations	P2P, star	P2P, star, mesh	P2P, mesh
Data Rate	1 Mbps	20-60 kbps	250 kbps
Security	128 AES	128 AES	128 AES

Figure 14 Technology Comparison: BLE, ANT, and Zigbee

Source: Mobile Experts

802.15.4 ZIGBEE AND 802.15.4J

ZIgbee technology is used for some products such as blood pressure monitors and weight scales, and in the hospital environment the 802.15.4j standard is invoked in some cases to use the 2360-2400 MHz band (set aside in the USA for body-area-networks at low power).

The Zigbee stack allows for very low power operation, and open reference designs from multiple companies makes a good environment for developers that want to tweak the Zigbee protocol in some way to suit their application.

The basic modulation format is offset-quadrature phase shift key, which allows asynchronous operation from multiple devices and maintains a low peak-to-average ratio for efficient amplifier operation. Zigbee can reach about 250 kbps in a 2 MHz channel.

802.15.6

The IEEE developed 802.15.6 standards for Wireless Body Area Networks (WBANs) for real-time health monitoring and some consumer electronics applications. The concept is to use a wearable device as a hub, so that multiple sensors such as EEGs, ECGs, blood pressure cuffs, thermometers, and others can aggregate their data in a single hub.

The first link in this concept can use 802.15.6 WBANs at 400 MHz or at 2360-2400 MHz, with the hub device using Wi-Fi or another high-throughput technology to relay data back to a gateway.

802.15.6 can achieve relatively high throughput, in the range of 4.5 Mbps for applications such as EEG real-time data. Commercial products (often using the term UWB for Ultra-WideBand) have not appeared in large numbers, with only light support from the semiconductor world.

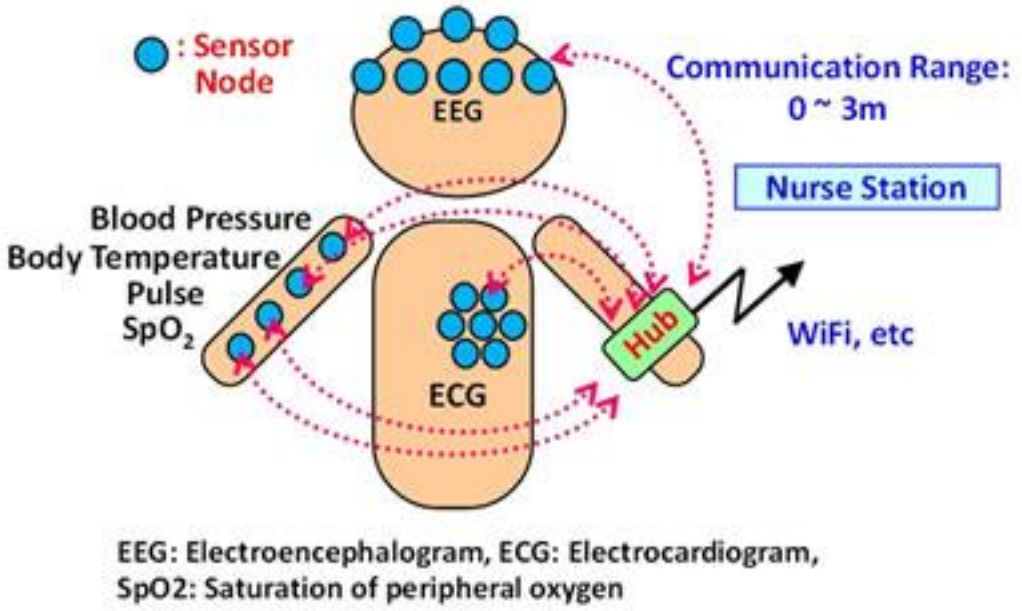

Figure 15 Use of Body Area Networks

Source: Fujitsu

Wi-Fi

Wi-Fi is far too power-hungry for wearable devices, but there are a few cases where Wi-Fi comes into play:

- Large devices such as weight scales often use Wi-Fi, especially if the use case involves occasional use in the bathroom where the smartphone is not likely to be present for tethered use.
- Medical wearable devices that include voice functionality are still based on Wi-Fi in some cases. These were among the first medical wearable devices, but they are essentially unchanged from introduction 10 years ago and BLE devices have overwhelmingly taken over in the growth applications.

Wi-Fi is utilized more often in hospital equipment that must communicate over a wider range. Real-time location systems, portable X-ray machines, IV pumps, and blood gas analyzers are all examples of portable machines that link data back to the hospital's server. Strictly speaking, most of these devices are not IoT devices because there's a human user that operates the X-ray machine or blood gas analyzer….so these devices are not included in the Mobile Experts IoT forecast.

Figure 16 Examples of Wi-Fi data collection tools in the hospital

Source: FDA

GSM, 3G, AND LTE

As with Wi-Fi, cellular technologies are power-hungry, so wearable devices don't utilize 2G, 3G, or 4G technology. These technologies use frequencies ranging from 700 MHz to 2.6 GHz, generally with high power transmitters (up to 3W, or 250 mW for small devices). 3G and LTE standards are tailored for high data throughput, from 300 kbps up to 30 Mbps, but GSM technology is more suited to about 5-10 kbps with wide coverage in all locations.

Because of battery life issues, these radios are generally only used as a "backhaul" link for wearables. Wearable devices report data over BLE to a smartphone, which then in turn transmits data to the cloud application over LTE or other mobile standards.

In this way, for wearable applications there is really no change to the existing market for LTE devices. The BLE device is taking advantage of the LTE radio which is already present in the smartphone.

On the other hand, LTE is attractive for medical devices that are used by patients, because there's no need to set up the device on Wi-Fi, Bluetooth, or any other platform. The higher cost associated with an LTE model and the service contract, however, have prevented the device OEMs from using LTE widely.

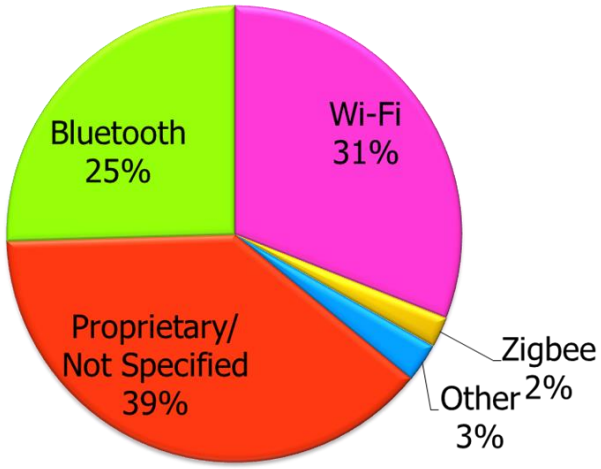

Figure 17 Breakdown of Wireless Format used for 350 FDA certified medical devices

Source: FDA

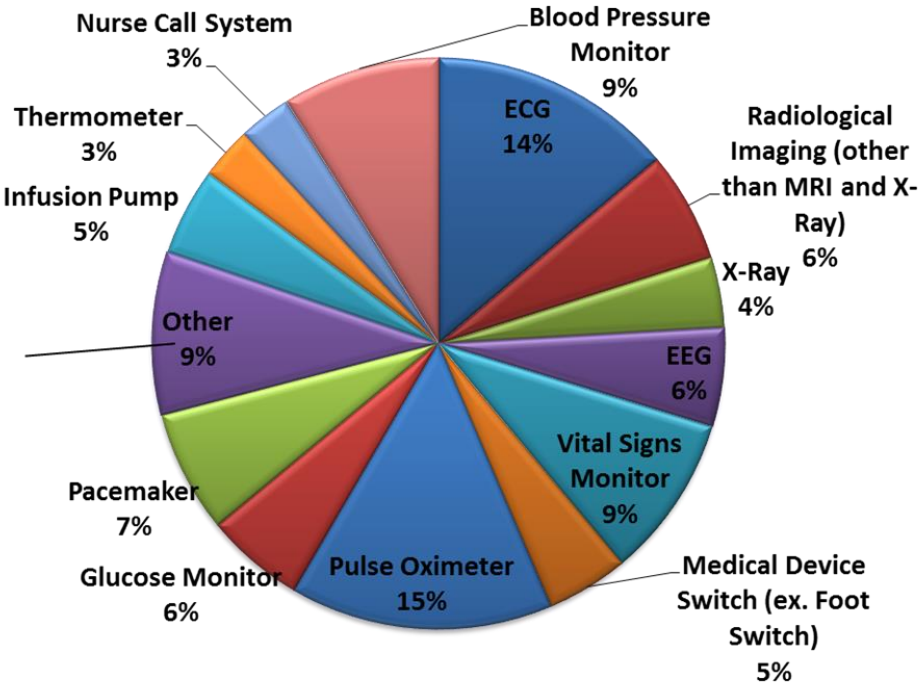

Figure 18 Breakdown of Application for 350 FDA certified medical devices

Source: FDA

5 OUTLOOK FOR HEALTHCARE IOT

Medical telemetry has been in place for a long time, but as the medical market moves toward collecting data on the cloud, we expect significant growth in new formats. In particular, the wearables market will grow rapidly over the next five years.

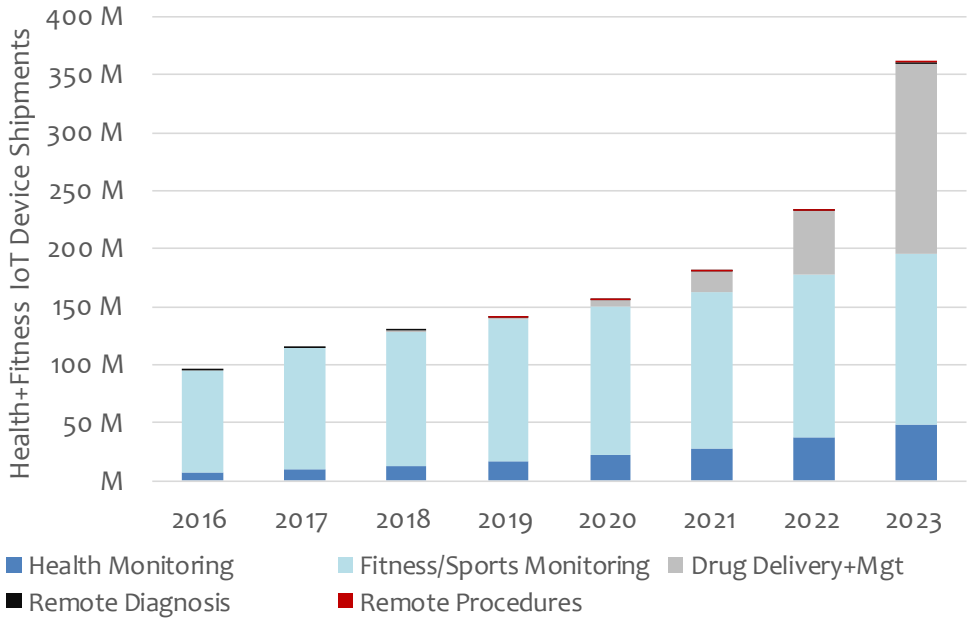

Chart 2: Healthcare + Fitness IoT Devices, by application, 2016-2023

Source: Mobile Experts.

MEDICAL MONITORING DEVICES

A wide variety of wireless formats are used to connect devices for monitoring key health factors. Because of the wide variety of sensors employed in healthcare, very different companies bring the products to market. Inevitably, the market is fragmented in terms of the radio standards used.

MICS devices are a solid entrenched technology for implanted devices, but for external devices, Bluetooth will be taking over with major growth due to outpatient use. The convenience of BLE, tethered to a smartphone, will overpower Zigbee and other formats during the next 2 years. When NB-IoT is widely available, we expect that NB-IoT will begin to compete favorably in data collection from home medical devices as well.

We've included ANT with Bluetooth in our estimates for the medical market, as ANT+ is more specialized in the fitness area.

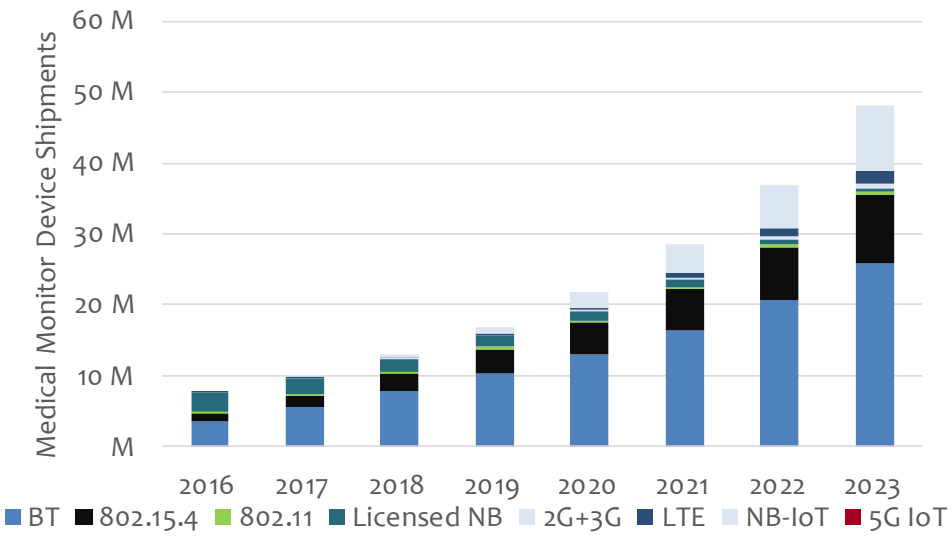

Chart 3: Medical Monitoring IoT Devices, by connectivity format, 2016-2023

Source: Mobile Experts.

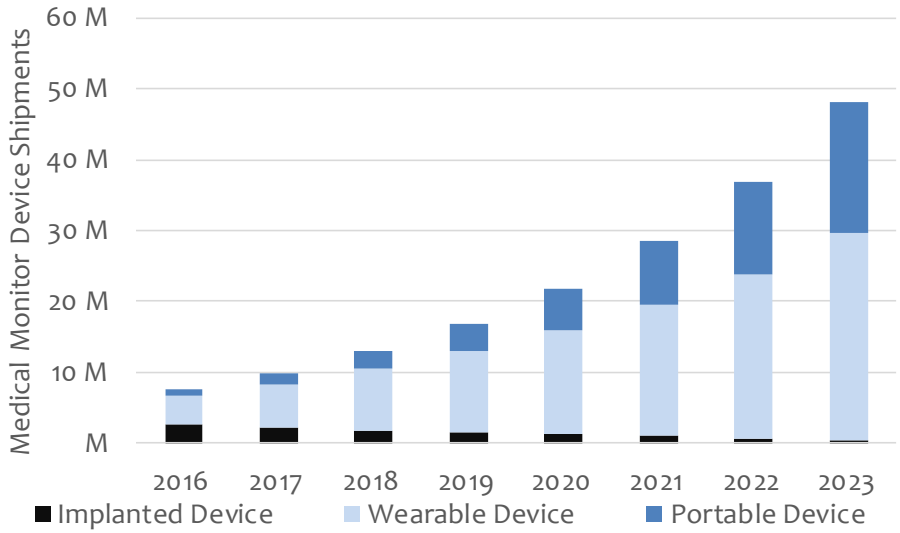

Chart 4: Medical Monitoring IoT Devices, implanted vs wearable vs portable, 2016-2023

Source: Mobile Experts.

FITNESS + SPORTS IOT DEVICES

The consumer market for fitness devices is more monolithic than the medical area. Heartrate monitors will grow up to offer more functionality, but in terms of connectivity we expect that the fitness market will remain devoted to Bluetooth. Some applications will migrate to NB-IoT but we don't expect the numbers to be significant because power consumption and will not be competitive with BLE. In the 2021 timeframe, we have a small entry for 5G devices to take advantage of the very low latency in this format—which should prove useful in some high-speed sports applications.

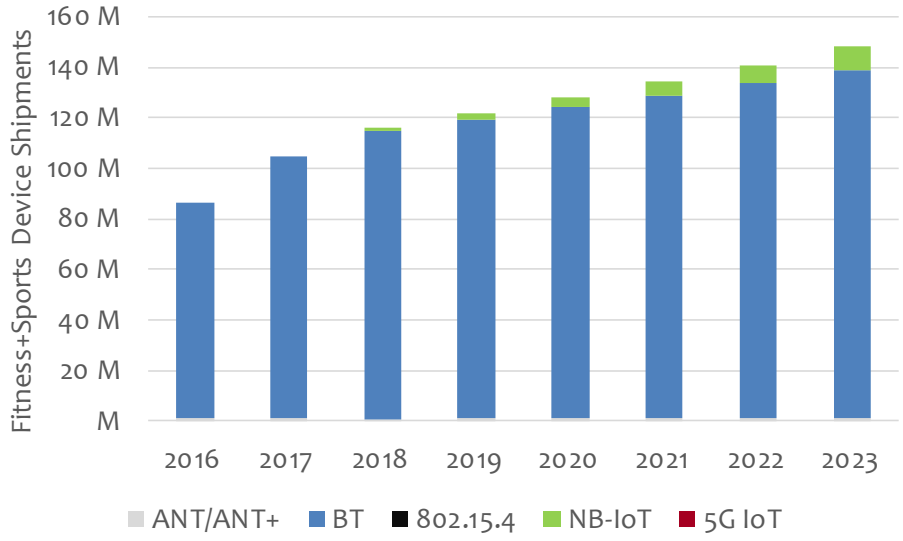

Chart 5: Fitness and Sports IoT Devices, by connectivity format, 2016-2023

Source: Mobile Experts.

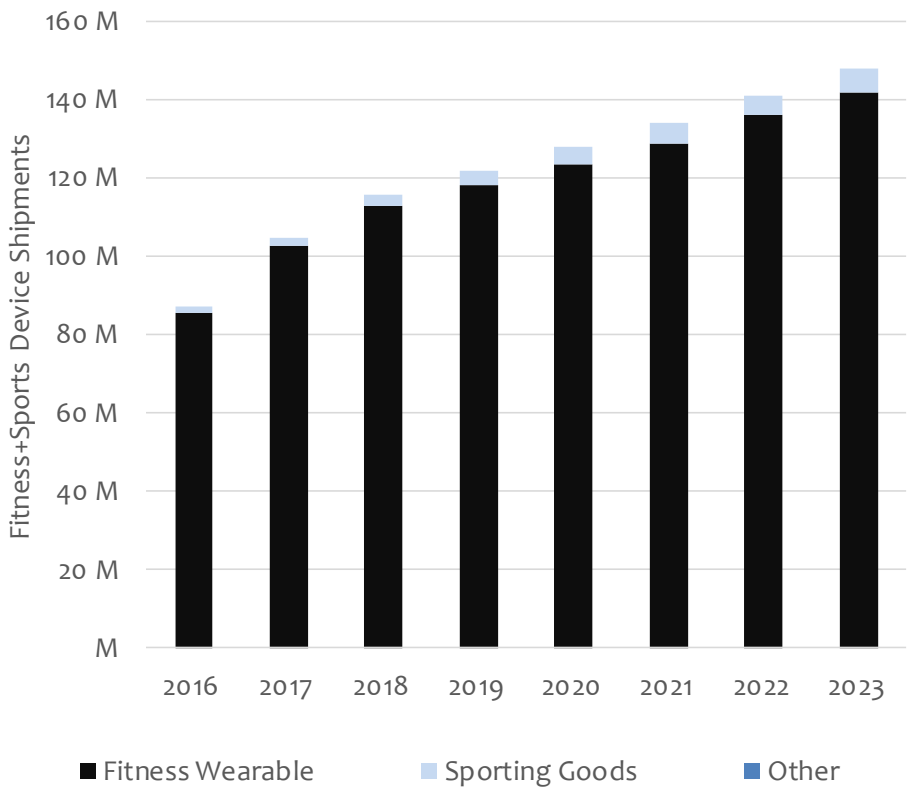

Chart 6: Fitness and Sports IoT Devices, by application, 2016-2023

Source: Mobile Experts.

DRUG DELIVERY AND MEDICINE MANAGEMENT DEVICES

In managing medication for patients, simple devices have already reached the market to track activity in the pill bottle. These applications have been dominated by Wi-Fi technology (for low cost) and LTE, because of the ease of setting up the radio so that the end user doesn't need to do anything at all. (After all, if they're not taking their pills, we shouldn't expect them to set up the app). We will probably see some LoRa variations on the "smart pill bottle", in regions where these formats are preferred.

The next step is to manage drug delivery in a wearable device or an implanted device. In these cases, Bluetooth or MICS technology are likely to be used, respectively. The Artificial Pancreas is the classic case of a device that could measure glucose levels and adjust insulin in a closed-loop algorithm. This level of sophistication will take a long time and many trials before it can be trusted. In our forecast, we have only trial quantities through 2020-2021.

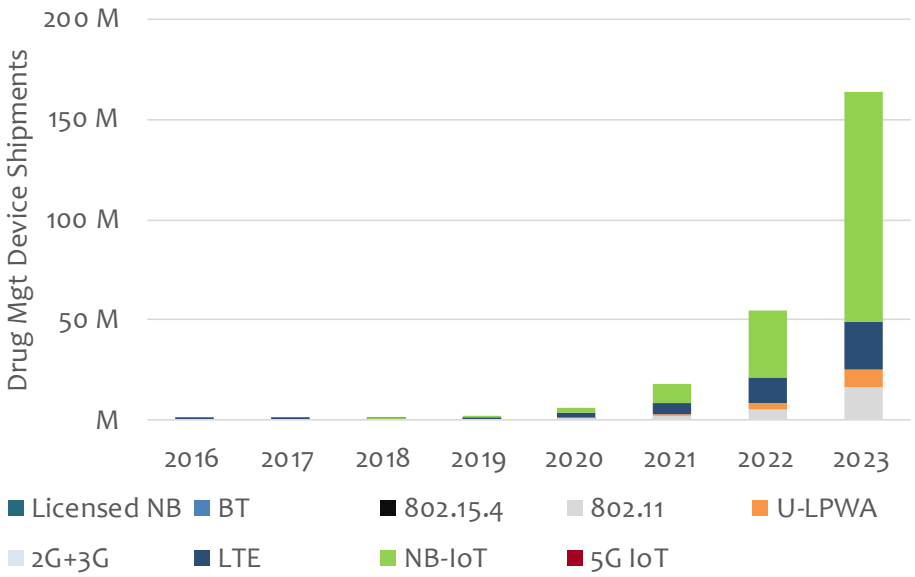

Chart 7: Drug Delivery and Management Devices, by connectivity format, 2016-2023

Source: Mobile Experts.

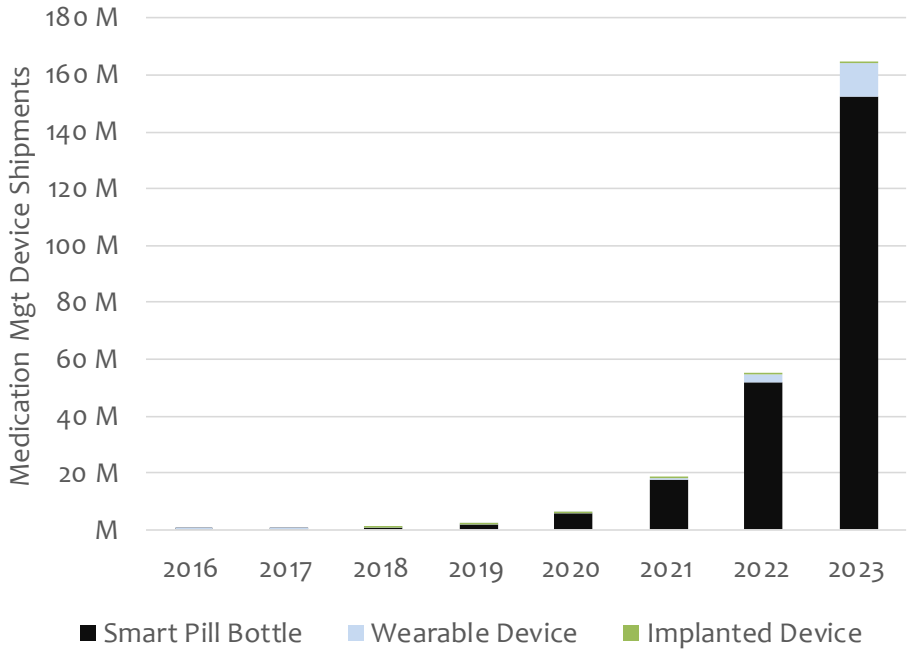

Chart 8: Drug Delivery and Management Devices, by device type, 2016-2023

Source: Mobile Experts.

REMOTE DIAGNOSIS (TELEMEDICINE DATA)

Videoconferencing for telemedicine applications is not counted in our IoT forecast, so this category focuses on remote applications of advanced sensors in a field situation. For example, an ambulance with blood oxygen sensors, ECGs, and other devices that are normally hospital-based must be outfitted with different connectivity to be used in a field situation. These applications will focus primarily on LTE connectivity in the near term, with some of the bursty data applications migrating to NB-IoT in order to reduce cost and battery power in the future.

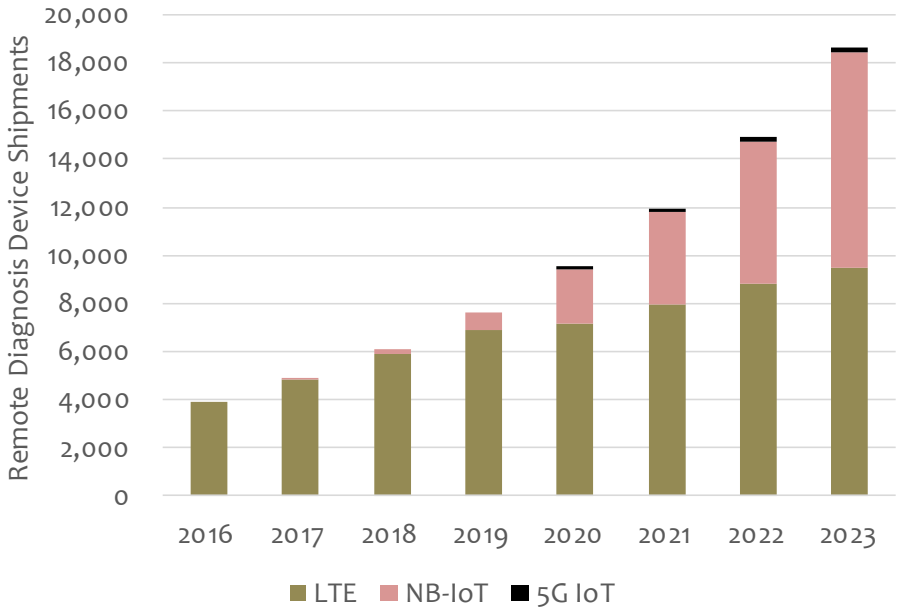

Chart 9: Remote Diagnostic Devices, by connectivity format, 2016-2023

Source: Mobile Experts.

REMOTE PROCEDURES/REMOTE SURGERY

In order to effectively allow a doctor to operate a machine remotely, some basic technology steps must be overcome to reduce latency. In our outlook, we have a small forecast for these devices based on LTE technology, transitioning to 5G technology when it becomes available. This market really is not mature enough to grow until after the 2021 timeframe.

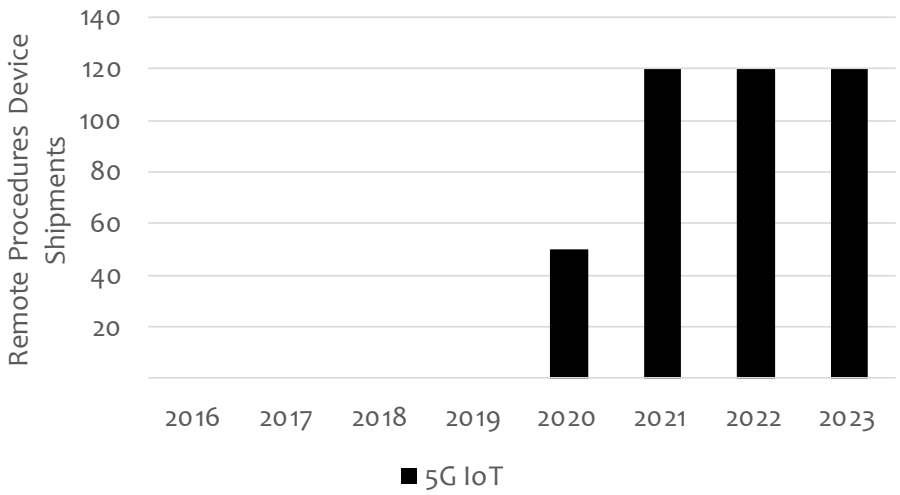

Chart 10: Remote Procedures/Surgical Devices, by connectivity format, 2016-2023

Source: Mobile Experts.

HEALTH + FITNESS IOT—TOTAL MARKET REVENUE

The overall trend toward government oversight of healthcare, as well as the trend toward "wellness" and monitoring will drive this overall market from its current size of roughly $12 billion to more than $100 billion in 2021. The bulk of the revenue growth will go into new sensors, platforms, analytics, and software.

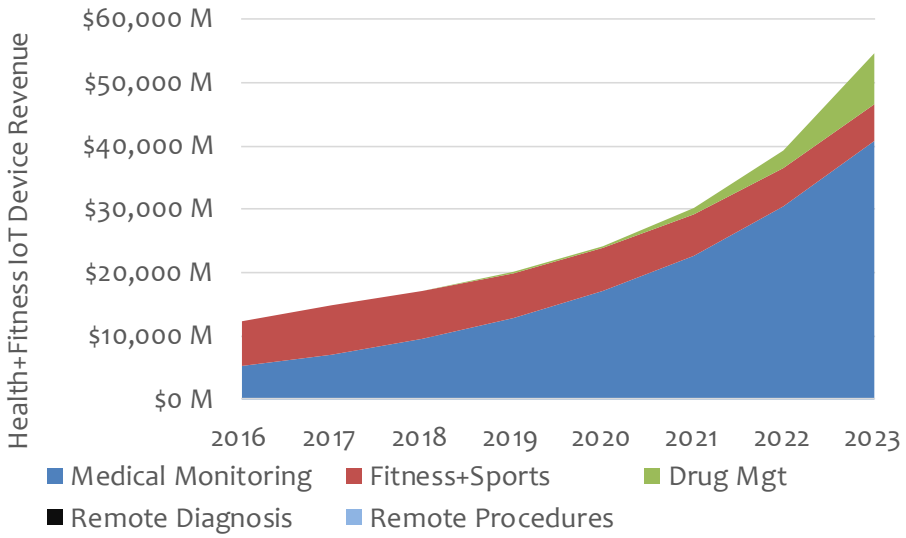

Chart 11: Revenue for Health + Fitness IoT Devices, by application, 2016-2023

6 ACRONYMS

2G: Second Generation Cellular
3G: Third Generation Cellular
3GPP: Third Generation Partnership Project
4G: Fourth Generation Cellular
5G: Fifth Generation Cellular
802.11: The IEEE working group for unlicensed local-area networks
802.11ah: IEEE standard for machine-to-machine networking below 1GHz
802.15.4: An IEEE standard which specifies PHY and MAC for low datarate personal area networks
802.15.4j A variation of 802.15.4 that extends to 2360-2400 MHz for medical applications
802.15.6: An IEEE standard (Ultra WideBand) for body area networks
ACA: Affordable Care Act (USA)
AES-128: Advanced Encryption Standard-128 bit
ANT/ANT+: A variation of Bluetooth for very low power consumption
BAN: Body Area Network
BLE: Bluetooth Low Energy
Bps: bits per second
BLE: Bluetooth Low Energy (Bluetooth 4.0+)
BT: Bluetooth
CFDA: China Food & Drug Administration
CGM: Continuous Glucose Monitoring
dBm: A measurement of radio signal strength
ECG: Electrocardiogram
EEG: Electro-encephalogram
FCC: Federal Communications Commission (USA)
FDA: Food and Drug Administration (USA)
FFS: Fee For Service
GFSK: Gaussian Frequency Shift Keying modulation
GHz: Gigahertz
GMSK: Gaussian Minimum Shift Keying modulation
GPRS: General Packet Radio Service
GSM: Global System for Mobile (2G cellular standard)
Hz: Hertz
IoT: Internet of Things
IPv6: Internet Protocol version 6
ISM: Instrumentation, Scientific, and Medical (a designation for unlicensed spectrum)
IV: Intravenous
Kbps: kilobits per second
kHz: Kilohertz
LAN: Local Area Network
LoRa: Long Range (a low power, wide area wireless format)

LPWA: Low Power Wide Area communciations
LTE: Long Term Evolution (a 4th generation cellular standard)
M2M: Machine-to-machine communications
MAC: Media Access Control
Mbps: Megabits per second
MCM: Multi-chip Module
MCU: Microcontroller Unit
MDD: Medical Device Directives (EU)
MDR: Medical Devices Requirements (EU)
MHz: Megahertz
MICS: Medical Implanted Communications
mW: milliwatts of power
NB-IoT: Narrowband IoT (a 3GPP based wireless standard)
P2P: Point to Point
PA: Power Amplifier
PAN: Personal Area Network
PMDA: Pharmaceuticals and Medical Devices Agency (Japan)
O-QPSK: Offset Quadrature phase shift keying modulation
OFDM: Orthogonal frequency division multiplexing
PHY: Physical layer
QAM: Quadrature Amplitude Modulation
QPSK: Quadrature Phase Shift Keying modulation
RED: Radio Equipment Directive (EU)
RFID: Radio Frequency Identification
RTLS: Real-Time Location System
SpO2: Measurement of arterial oxygen saturation
UWB: Ultra-wideband technology
VBP: Value Based Program or Value Based Pricing
W-CDMA: Wideband Code Domain Multiple Access, a 3G radio interface
WAN: Wide Area Network
Wi-Fi: Wireless Fidelity (refers to the broad family of 802.11 standards)
WMTS: Wireless Medical Telemetry Service

7 METHODOLOGY

Mobile Experts interviewed more than 30 companies ranging from insurance providers to hospitals, OEMs, and semiconductor suppliers to develop the information in this report. The bulk of the interviews took place in the supply chain, with device manufacturers and semiconductor suppliers providing details about connectivity and levels of semiconductor integration.

The scope of this report includes wearable devices for both fitness and medical applications. Mobile Experts chose to include these two categories together in one report, because the incentives of wellness programs blur the lines between "fitness tracking" and "medical insurance".

This report also includes multiple applications for drug delivery and management of medications, meaning patches and implants to deliver drugs and devices such as "smart pill bottles" which track the movement of the pill bottle and the removal of pills from the bottle. Smart pills are also considered, but Mobile Experts anticipates that large numbers of ingestible IoT devices will not be sold on the market for more than 5 years….therefore the numbers are not visible in our 5-year forecast.

This report also includes "Telemedicine" IoT devices. "Telemedicine" or "Telehealth" is such a broad and over-used term that it is not very meaningful. The video conferencing application is not covered in this report, as video conferencing involves human users, and therefore is not an IoT application. However, remote diagnostic sensors do represent an IoT application for remote doctor services. Blood pressure, ECG, EEG, temperature, etc are all measurements that can be performed on the patient and uploaded to a cloud application for review by a doctor located elsewhere. These devices are covered in the forecast.

Finally, the scope of this report includes remote procedures or remote surgical devices. These devices are often discussed but are not available today due to the slow speed of connections and the difficulty in remotely controlling such fine precision tools. We expect that with advanced LTE and 5G networks, these systems will be used in the field in small numbers….these are reflected in the 5-year forecast presented in this report.